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Trends in the Prevalence of Obstructive and Restrictive Lung Function Among Adults in the United States:

Findings From the National Health and Nutrition Examination Surveys From 1988-1994 to 2007-2010

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Abstract

Background—National spirometric surveillance data in the United States were last collected during 1988-1994. The objective of this study was to provide current estimates for obstructive and restrictive impairment of lung function and to examine changes since 1988-1994.

Methods—We used data from 14,360 participants aged 20 to 79 years from the National Health and Nutrition Examination Survey (NHANES) III (1988-1994) and 9,024 participants from NHANES 2007-2010. Spirometry was conducted using the same spirometers and generally similar protocols.

Results—During 2007-2010, 13.5% (SE, 0.6) of participants had evidence of airway obstruction (FEV_1/FVC, <0.70): 79.9% of adults had normal lung function, 6.5% had a restrictive impairment, 7.5% had mild obstruction, 5.4% had moderate obstruction, and 0.7% had severe obstruction. Although the overall age-adjusted prevalence of any obstruction did not change significantly from 1988-1994 (14.6%) to 2007-2010 (13.5%) (P = .178), significant decreases were noted for participants aged 60 to 79 years and for Mexican Americans. The prevalence of current smoking remained high among participants with moderate (48.4%) and severe (37.9%) obstructive impairments. A significant decline in current smoking occurred only among those with normal lung function (P < .05).

Conclusion—Spirometry revealed little change in the prevalence of any obstructive and restrictive impairment in lung function during 2007-2010, compared with 1988-1994.

Spirometry is a valuable tool for assessing respiratory health in populations. In the United States, spirometry has been used in several national surveys, with the last such assessment taking place between 1988 and 1994. Consequently, updated information is of interest in characterizing the respiratory health of the US population and in measuring progress toward national goals.

Previous spirometric surveillance showed that about 15% of adults aged 25 to 74 years had some degree of obstructive impairment of lung function during 1988-1994.[1] In another analysis of the same data, approximately 6% of adults aged ≥ 17 years had restrictive abnormalities.[2] Numerous respiratory insults contribute to COPD, with major causes including smoking, occupational exposures, and, in some countries, indoor sources of combustion.[3,4] Air pollution has also been implicated as a risk factor for COPD.[5] In the United States, data from the National Health Interview Survey showed that the prevalence of current smoking among adults decreased from 25.5% of adults in 1990 to 19.3% in 2010.[6] Furthermore, air quality in the United States has improved markedly since 1990.[7] Theoretically, the favorable trends of these noxious lung irritants should have led to improvements in respiratory health. Therefore, our objective was to provide updated estimates of the prevalence of obstructive and restrictive impairments of respiratory function among adults in the United States.

Materials and Methods

The current study included data from the National Health and Nutrition Examination Survey (NHANES) III (1988-1994) and NHANES 2007-2010. In these surveys, participants were

selected by using a stratified multistage probability sampling design. After agreeing to participate, invitees were interviewed in their homes and offered an opportunity to attend an examination in the mobile examination center, where they were asked to complete additional questionnaires, undergo various examinations, and provide a blood sample. Response rates for the interview and examination were 86% and 78%, respectively, in NHANES III, 78% and 75%, respectively, in NHANES 2007-2008, and 79% and 77%, respectively, in NHANES 2009-2010. Details about the surveys may be found elsewhere.[8,9] Because we used data freely available in the public domain, our study was exempt from human subjects review.

All adults in NHANES III were offered a pulmonary function test, and protocols for these measurements have been summarized previously.[2,10] In NHANES III, participants were excluded for the following reasons: self-reported chest or abdominal surgery within the previous 3 weeks and hospitalization for a heart problem within the previous 6 weeks. Spirometry was offered to participants aged 6 to 79 years in NHANES 2007-2010.[11,12] Participants were excluded for the following reasons: current chest pain; physical problem with forceful expiration; use of supplemental oxygen; recent surgery of the eye, chest, or abdomen; recent heart attack, stroke, tuberculosis exposure, or coughing up of blood; and history of detached retina, collapsed lung, or aneurysm (Table 1). For the three surveys, the protocols for conducting spirometry were similar, and the spirometers that were used were the same (Ohio 822/827 dry-rolling seal volume spirometers).[12] One noteworthy difference was that participants of NHANES III attempted as many as eight maneuvers with the goal of obtaining five acceptable maneuvers. In contrast, participants of NHANES 2007-2010 were asked to provide three acceptable maneuvers.

We used predictive equations for FEV_1 and FVC, as well as a lower limit of normal equations for FEV_1/FVC that were derived from NHANES III data.[10] These equations, for FEV_1 and FVC, which were developed separately for demographic groups based on sex, race or ethnicity, and age, included age, age-squared, and height as variables. We adapted the Global Initiative for Chronic Obstructive Lung Disease classification of COPD severity based on postbronchodilator spirometric results to establish the following categories of obstructive impairment: severe obstructive impairment (FEV_1/ FVC,<.70 and FEV_1 <50% predicted), moderate obstructive impairment (FEV_1/FVC < 0.70 and FEV_1 50% to < 80% predicted), and mild obstructive impairment (FEV_1/FVC < 0.70 and $FEV_1 \geq 80\%$ predicted). Participants with an FEV_1/FVC ratio ≥ 0.70 were considered not to have obstructive impairment.[13] In addition, we defined a category of restrictive impairment (FEV_1/FVC ≥ 0.70 and FVC < 80% predicted). We calculated the prevalence of airway obstruction using an alternative approach on which an obstructive impairment was defined as FEV_1/FVC < predicted ratio of FEV_1/FVC based on the lower limit of normal.[10]

We included the following covariates: age, sex, self-reported race or ethnicity (white, Black, and Mexican American), educational level (< 12 years, high school graduate or equivalent, education beyond high school), and smoking status (current, former, never). A current smoker was defined as someone who had smoked ≥ 100 cigarettes during his or her lifetime and reported smoking currently. A former smoker was defined as someone who had smoked ≥ 100 cigarettes during his or her lifetime but reported having stopped smoking. A never

smoker was defined as someone who had not smoked ≥ 100 cigarettes during his or her lifetime.

The analyses were limited to participants aged 20 to 79 years who had a spirometric examination in the mobile examination center. We combined data for the surveys conducted during 2007-2008 and 2009-2010 and compared the results for these 4 years of data with the results generated from NHANES III data. When done, we adjusted the data for age using the direct method and the projected year 2000 US population for adults aged 20 to 79 years using three age groups (20-39 years, 40-59 years, and 60-79 years). We present age-specific and age-adjusted mean levels of FEV_1 and FVC, as well as percent predicted FEV_1 and FVC for groups defined by selected characteristics and survey years. For categorical data with more than two categories, we used the Cochran-Mantel-Haenszel test with the three age groups as the stratifying variable to test for significant differences in the prevalence of lung function abnormalities. For categorical variables with two categories and means, we used *t* tests to examine differences in proportions and means. Analyses were conducted in SAS and SUDAAN (RTI International), the latter to account for the complex sampling design of the surveys. Sampling weights were used to produce estimates (means and percent-ages) that are representative of the civilian noninstitutionalized population in the United States. Sample sizes shown in the text and tables are unweighted numbers.

Results

Of the 15,331 participants aged 20 to 79 years who had an examination in NHANES III, 14,360 had values for FEV_1 and FVC. Of the 10,981 participants aged 20 to 79 years who had an examination in NHANES 2007-2010, 819 were excluded from participation in the spirometric examination (Table 1). Among those eligible, 9,172 participated in the spirometric examination, and 9,047 had values for FEV_1 and FVC. After excluding participants who lacked a value for height, 9,024 were included in the analysis. Compared with participants from NHANES III, those in the more recent survey were a little older, slightly more likely to be male, less likely to be white, more likely to have graduated from high school, and less likely to be currently smoking (Table 2).

Pulmonary Function Parameters

Among all participants, significant increases in the age-adjusted mean levels of FEV_1 and FVC were noted (Table 3). Furthermore, significant increases in mean levels of FEV_1 and FVC were noted for women, participants aged 60 to 79 years, whites, high school graduates or equivalent, and participants who never smoked (all, $P < .05$). Significant increases in both percent predicted FEV_1 and percent predicted FVC were observed for all participants, women, participants aged 60 to 79 years, and participants with less than a high school education ($P < .05$) (Table 4). In addition, significant increases for percent predicted FVC were noted for whites, current smokers, and never smokers ($P < .05$).

Sensitivity Analyses—Because of differences in the exclusion criteria for the spirometric examinations in the two surveys, we recalculated the mean FEV_1 and FVC for the period 2007-2010 under two scenarios: (1) we assigned the mean values for FEV_1 and FVC of participants with a severe obstructive impairment to everyone who used oxygen and (2) we

assigned the mean values for FEV_1 and FVC of participants with a severe obstructive impairment to everyone who used oxygen and reported having COPD and to everyone who reported having a problem taking a deep breath and reported having COPD. The increase in the age-adjusted mean FEV_1 for the two time periods changed from the original 53 mL (P = .012) to 42 mL under scenario 1 (P = .044) and to 43 mL under scenario 2 (P = .039). The increase in the age-adjusted mean FVC for the two time periods changed from the original 72 mL (P = .008) to 65 mL under scenario 1 (P = .017) and to 65 mL under scenario 2 (P = .015).

Pulmonary Function Impairment

After age adjustment, 79.9% of adults had normal lung function, 6.5% had restrictive impairment, 7.5% had mild obstruction, 5.4% had moderate obstruction, and 0.7% had severe or very severe obstruction during 2007-2010 (Table 5). Overall, 13.5% of adults in 2007-2010 showed evidence of any obstructive impairment, an estimate that was statistically similar to the prevalence of 14.6% for NHANES III (P = .178). Significant decreases in the age-adjusted prevalence of any obstructive impairment were noted only for participants aged 60 to 79 years and for Mexican Americans. During 2007-2010, the prevalence of any obstructive impairment was higher among men than among women (P < .001), increased with age (P for linear trend < .001), was higher among whites than among any of the other race or ethnic groups (P < .001 for all comparisons), was higher among those with a high school diploma or equivalent than among those with education beyond high school (P = .019), and was higher among current smokers than among former smokers or among those who never smoked (P < .001 for both comparisons).

Using an alternative definition for airway obstruction (lower limit of normal), no significant change in prevalence was observed among all adults aged 20 to 79 years (Table 6). Significant decreases occurred among participants aged 60 to 79 years and among Mexican Americans. After adjustment for age, sex, race or ethnicity, educational status, and smoking status, no significant change in the prevalence of any obstructive impairment using the GOLD (Global Initiative for Chronic Obstructive Lung Disease) approach was evident (Table 7).

Sensitivity Analyses—As mentioned previously, we recalculated the prevalence of having any obstructive impairment and the prevalence of having a severe obstructive impairment for the period 2007-2010 under two scenarios: (1) we assumed that everyone who used oxygen had a severe obstructive impairment and (2) we assumed that only those who reported using oxygen and reported having COPD, as well as those who reported having a problem taking a deep breath and reported having COPD, had a severe obstructive impairment. Under the first scenario, the age-adjusted percentages of participants who had any obstructive impairment and a severe obstructive impairment were 14.1% (SE, 0.6) (P vs NHANES III = .498) and 1.4% (SE, 0.1) (P vs NHANES III = .506), respectively. Under the second scenario, the age-adjusted percentages of participants who had any obstructive impairment and a severe obstructive impairment were 14.0% (SE, 0.6) (P vs NHANES III = .460) and 1.3% (SE, 0.1) (P vs NHANES III = .314), respectively. The results of sensitivity analyses of the regression analyses show no significant change in the prevalence

of any obstructive impairment or severe obstructive impairment after adjustment for age, sex, race or ethnicity, educational status, and smoking status (Table 7).

Lung Function Impairment and Smoking

Among participants with any obstructive impairment, the prevalence of current smoking remained high during 2007-2010 (mild, 36.4%; moderate, 48.4%; and severe, 37.9%) with minor nonsignificant decreases (Fig 1). Based on self-reported smoking status, the data indicated a large, albeit statistically nonsignificant, decrease in current smoking among participants with a severe obstructive impairment (from 53.6% to 37.9%, $P = .146$), but the decreases were unimpressive among those with mild or moderate impairment (mild, 4.1% decrease, $P = .345$; moderate, 2.2% decrease, $P = .668$). Current smoking declined significantly only among people with normal lung function between the surveys ($P < .001$).

Discussion

Since 1988-1994, the prevalence of any obstructive impairment of lung function has remained relatively stable among US adults. Noteworthy was that almost no participant had a very severe obstructive impairment ($FEV_1/FVC < 0.70$ and < 30% predicted FEV_1) of lung function during 2007-2010. The prevalence of restrictive impairment changed little.

We observed significant increases in the mean levels of FEV_1 and FVC and in the percent predicted FEV_1 and FVC, but no significant decline in the prevalence of any obstructive impairment from 1988-1994 to 2007-2010. The latter finding contrasts with declines in the prevalence of moderate-severe COPD based on pulmonary function observed between NHANES I (1971-1975) and NHANES III (1988-1994).[14] Differences in the exclusion criteria of the spirometric examinations for the two surveys included in the current study likely inflated to some degree the apparent favorable changes in FEV_1 and FVC that we described, in that more liberal exclusion criteria during 2007-2010 probably resulted in a higher percentage of participants with an obstructive impairment being excluded from having the examination. Consequently, participants who were included in the spirometric examination likely represented, from a respiratory health perspective, a somewhat healthier subset of all participants, and, thus, the estimates of lung function that we present may have overestimated somewhat the true respiratory health of all participants in the survey. Nevertheless, our sensitivity analyses suggested that the mean FEV_1 and FVC did increase.

Increases in population levels of FEV_1 and FVC, potentially reflecting reduced exposure to cigarette smoke and other noxious lung irritants, may indicate the need for updated and revised lung function standards. The continuing decline in the prevalence of smoking and in exposure to secondary smoke, along with improvements in environmental exposures such as air pollution, should have had a salutary effect on respiratory health. Smoking cessation has been shown to slow the decline of pulmonary function.[15-18] Furthermore, studies suggest that inhaled therapies may also slow the rate of decline of lung function.[19,20] However, further study is warranted to assess population-level trends in these factors. Our study observed that current smoking prevalence remained high among people with obstructive impairment. In addition, the changes, or lack thereof, in pulmonary function parameters shown in the current study also need to be considered in the context of the evolving

pharmacologic management of COPD, particularly the increasing use of long-acting inhaled agents.

The apparent drop in the prevalence of having a severe obstructive impairment may have been a consequence of changes in the exclusion criteria for participation in spirometry. In NHANES III, only two exclusion criteria were applied: chest or abdominal surgery within the previous 3 weeks or hospitalization for a heart problem within the previous 6 weeks. In contrast, the list of possible exclusions was expanded during NHANES 2007-2010 and included the use of oxygen for breathing problems. Because 107 participants reported using oxygen and were, therefore, not eligible for spirometry, the real prevalence of severe obstructive impairment was probably higher, assuming that many, if not most, of these participants would have had a severe obstructive impairment. Our sensitivity analyses attempted to explore this issue.

COPD continues to be a leading cause of morbidity and mortality in the United States. Our estimate of the unadjusted prevalence of any obstructive impairment of lung function of 13.7% suggests that, assuming an average population estimate for the years 2007-2010 of 211,257,900 adults aged 20 to 79 years, about 28.9 million adults aged 20 to 79 years had some degree of obstructive impairment of lung function: 15.9 million with mild obstructive impairment, 11.4 million with moderate obstructive impairment, and 1.5 million with severe or very severe obstructive impairment. In contrast, approximately 13.1 million adults in the United States were estimated to have COPD based on self-reported information in 2008.[21] In 2008, 141,090 deaths were attributed to chronic lower respiratory diseases, making it the third-leading cause of mortality, with > 95% of these deaths directly attributed to COPD.[22] Furthermore, people with COPD also suffer from impaired quality of life,[23] and the economic costs from COPD were estimated to be $49.9 billion in 2010.[24]

The principal risk factors for COPD in the United States are smoking and occupational and environmental exposures.[3-5] The prevalence of smoking has decreased substantially,[6] and air quality has improved since 1990.[7] Exposure to environmental tobacco smoke, which has also been linked to COPD,[25] declined from 1988-1994 to 1999-2002 in the United States.[26] Subsequent to this latter period, however, geometric mean levels remained relatively unchanged.[27] Consequently, the relatively stable prevalence of obstructive impairment of lung function based on spirometric data in the face of improvements in important determinants of COPD is disappointing and unanticipated. The reasons for this muted change are unclear.

The results presented in this paper are subject to various limitations. We have already discussed the possible ramifications of changes in the exclusion criteria for spirometry. Generally, the protocols for conducting spirometry were similar for the surveys. The one major change was the requirement for at least five acceptable maneuvers in NHANES III compared with three in NHANES 2007-2010. An analysis of NHANES III showed that FEV_1 and FVC were 52 mL and 62.5 mL lower, respectively, when three acceptable and reproducible maneuvers were used rather than the original five to eight maneuvers that were obtained.[10] Furthermore, a comparison of data from the Multi-Ethnic Study of Atherosclerosis, which used three acceptable maneuvers with predicted values using

NHANES III derived equations, suggested that the use of three maneuvers could have resulted in measurements of FEV_1 and FVC that were lower in whites, Black men, and non-Mexican Hispanics (largest reductions, FEV_1 by 177 mL and FVC by 224 mL in Black men) but higher in Black women and Mexican Americans.[28] Although such differences would have had a negligible effect on the calculation of the FEV_1/FVC ratio, the observed to predicted ratio of FEV_1 could have been affected, leading to some degree of underestimate or overestimate of the percentages of adults with an obstructive impairment of lung function. Treatment patterns for COPD changed over time. Thus, the distribution of obstructive impairment could conceivably have looked more favorable during 2007-2010 than during 1988-1994 if increased and improved treatment of COPD during 2007-2010 led to better performance of lung function testing. Finally, the protocol for spirometric testing in NHANES III did not include post-bronchodilator testing, and, consequently, we were not able to assess the change over time in obstructive lung function based on postbronchodilator testing. Some percentage of participants with asthma may have been included in our estimates. If this percentage remained reasonably stable for the two time periods, the temporal changes in pulmonary function that we examined may not have been affected.

Conclusions

The estimates of obstructive impairment of lung function based on spirometric data presented in this study suggest that COPD continues to be a serious public health problem and raise questions about how much, if any, progress has been achieved in the prevention of this disease. Future progress in reducing the prevalence of COPD will depend on further success in reducing the key risk factors for this disease: smoking, occupational exposures, and air pollution. Continued surveillance with spirometry is critical to charting the future course of the respiratory health of the US population.

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Abbreviations

NHANES	National Health and Nutrition Examination Survey

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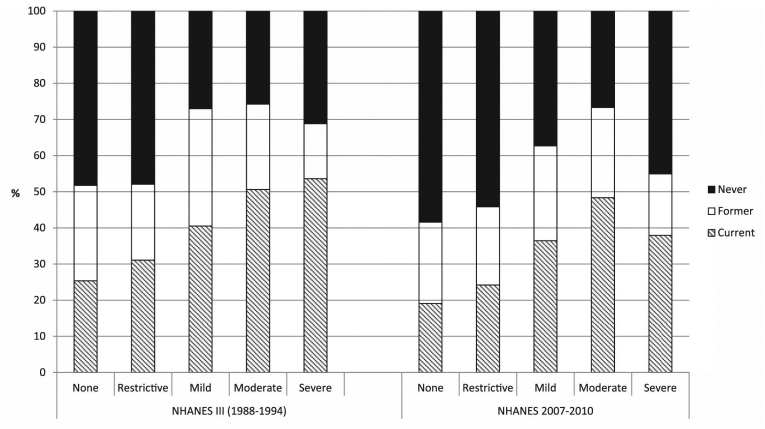

Figure 1.

Age-adjusted percentages of current, former, and never smoking status among adults aged 20 to 79 years, by categories of lung function impairment and NHANES survey. NHANES = National Health and Nutrition Examination Survey.

Table 1

Numbers of Participants Aged 20 to 79 Years Excluded From Having Spirometry in NHANES

Exclusion Criteria	NHANES III	NHANES 2007-2010
Aged 20-79 y and attending examination	15,331	10,981
Chest or abdominal surgery within previous 3 wk	4	…
Myocardial infarction or heart attack	4	…
Breathing problem requiring oxygen	…	107
Problem taking deep breath	…	189
Eye surgery in the previous 3 mo	…	78
Chest/abdominal surgery in the previous 3 mo	…	72
Tuberculosis in the previous year	…	35
Ever told had an aneurysm	…	73
Ever told had a collapsed lung	…	112
Ever told had a detached retina	…	93
Stroke in the previous 3 mo	…	13
Heart attack in the previous 3 mo	…	8
Coughed up blood in the previous mo	…	41

Two participants in NHANES 2007-2010 had two exclusion criteria each. NHANES 5 National Health and Nutrition Examination Survey.

Table 2

Unadjusted Means or Percentages of Selected Characteristics of Adults Who Performed Spirometry, by NHANES Survey

	NHANES III (1988-1994)		NHANES 2007-2010		
Characteristics	**No.** [a]	**Mean or % (SE)**	**No.** [a]	**Mean or % (SE)**	***P* Value**
Age, y (mean, SE)	14,360	43.1 (0.4)	9,024	44.8 (0.4)	.001
Men (%, SE)	6,729	48.3 (0.4)	4,487	49.6 (0.5)	.029
Race or ethnicity (%, SE)					.009
White	5,539	76.5 (1.2)	4,201	68.9 (2.5)	
Black	4,166	10.8 (0.6)	1,729	11.0 (1.0)	
Mexican American	4,085	5.1 (0.4)	1,676	8.7 (1.3)	
Other	570	7.6 (0.8)	1,418	11.4 (1.3)	
Education (%, SE)					< .001
< High school	5,470	23.3 (1.0)	2,464	17.8 (0.9)	
High school graduate or equivalent	4,533	34.1 (0.7)	2,145	23.8 (0.9)	
> High school	4,271	42.7 (1.3)	4,406	58.5 (1.5)	
Smoking status (%, SE)					< .001
Current	3,988	29.4 (0.8)	2,118	22.3 (0.8)	
Former	3,403	25.4 (0.6)	2,,086	23.4 (0.9)	
Never	6,968	45.2 (0.8)	4,816	54.3 (1.3)	
BMI, kg/m ^{2} (mean, SE)	14,345	26.6 (0.1)	9,021	28.7 (0.1)	< .001

See Table 1 legend for expansion of abbreviations.

[a] Unweighted sample size. Sample sizes for education and smoking status add to less than 14,360 due to missing data for these variables.

Table 3

Age-Adjusted and Age-Specific Means of Pulmonary Function Parameters Among US Adults Aged 20 to 79 Years: Observed Mean Level

Characteristics	NHANES III (1988-1994)			NHANES 2007-2010			*P* Value (FEV_1)[a]	*P* Value (FVC)[a]
	No.[b]	FEV_1, mL	FVC, mL	No.[b]	FEV_1, mL	FVC, mL		
Total	14,360	3,176.8 (15.6)	4,064.0 (18.5)	9,024	3,229.8 (13.4)	4,136.4 (19.0)	.012	.008
Men	6,729	3,699.3 (19.9)	4,806.4 (22.3)	4,487	3,725.6 (17.3)	4,831.4 (23.1)	.322	.438
Women	7,631	2,686.6 (12.3)	3,371.0 (15.2)	4,537	2,739.0 (11.4)	3,450.6 (15.8)	.002	< .001
Age								
20-39 y	6,524	3,662.1 (21.1)	4,474.8 (26.8)	3,318	3,681.5 (20.1)	4,530.8 (26.0)	.508	.137
40-59 y	4,184	3,095.0 (19.1)	4,043.5 (22.4)	3,229	3,127.8 (20.4)	4,083.6 (26.8)	.243	.255
60-79 y	3,652	2,300.6 (21.1)	3,224.3 (23.7)	2,477	2,466.4 (22.5)	3,396.8 (29.4)	< .001	< .001
Race or ethnicity								
White	5,539	3,265.8 (19.2)	4,200.6 (21.4)	4,201	3,342.5 (19.2)	4,314.9 (20.7)	.006	< .001
Black	4,166	2,787.7 (15.4)	3,495.9 (20.4)	1,729	2,812.3 (19.3)	3,542.8 (24.7)	.324	.147
Mexican American	4,085	3,131.8 (17.0)	3,896.2 (18.1)	1,676	3,174.7 (21.0)	3,951.5 (27.9)	.117	.100
Other	570	2,869.5 (33.0)	3,590.4 (40.6)	1,418	3,001.1 (30.2)	3,767.0 (37.3)	.004	.002
Education								
< High school	5,470	2,980.6 (18.9)	3,835.3 (24.8)	2,464	3,048.5 (19.8)	3,915.5 (31.5)	.015	.049
High school graduate or equivalent	4,533	3,103.2 (18.0)	3,976.3 (25.5)	2,145	3,197.3 (21.3)	4,110.0 (29.5)	.001	.001
> High school	4,271	3,342.9 (23.4)	4,262.3 (26.9)	4,406	3,301.7 (18.2)	4,219.4 (25.6)	.169	.251
Smoking status								
Current	3,988	3071.8 (16.7)	4048.9 (20.1)	2,118	3,115.7 (24.3)	4,148.6 (30.0)	.140	.007
Former	3,403	3330.2 (26.4)	4294.6 (30.6)	2,086	3,338.2 (25.4)	4,302.0 (32.3)	.827	.867
Never	6,968	3138.2 (20.6)	3915.0 (25.5)	4,816	3,230.9 (18.2)	4,064.9 (25.5)	.001	< .001

Data are presented as mean (SE). See Table 1 legend for expansion of abbreviations.

[a] *P* value for test of difference in means between the two time periods.

[b] Unweighted sample size. Sample sizes for education and smoking status add to less than 14,360 due to missing data for these variables.

Table 4

Age-Adjusted and Age-Specific Means of Pulmonary Function Parameters Among US Adults Aged 20 to 79 Years: Percent Predicted

Characteristics	NHANES III (1988-1994) No. [b]	NHANES III (1988-1994) FEV_1, % predicted	NHANES III (1988-1994) FVC, % predicted	NHANES 2007-2010 No. [b]	NHANES 2007-2010 FEV_1, % predicted	NHANES 2007-2010 FVC, % predicted	*P* Value (FEV_1)[a]	*P* Value (FVC)[a]
Total	14,360	94.6 (0.3)	97.2 (0.3)	9,024	95.6 (0.3)	98.2 (0.3)	.028	.017
Men	6,729	94.2 (0.4)	97.3 (0.3)	4,487	94.8 (0.4)	97.5 (0.4)	.293	.650
Women	7,631	94.9 (0.3)	97.1 (0.3)	4,537	96.4 (0.3)	98.9 (0.3)	.002	< .001
Age								
20-39 y	6,524	97.8 (0.4)	99.3 (0.4)	3,318	97.8 (0.3)	100.2 (0.4)	.964	.093
40-59 y	4,184	93.5 (0.4)	96.4 (0.4)	3,229	94.6 (0.5)	97.2 (0.4)	.086	.128
60-79 y	3,652	89.9 (0.6)	94.1 (0.5)	2,477	92.9 (0.6)	95.8 (0.5)	.001	.012
Race or ethnicity								
White	5,539	94.6 (0.4)	97.5 (0.4)	4,201	95.8 (0.4)	98.8 (0.4)	.052	.012
Black	4,166	96.5 (0.3)	99.0 (0.3)	1,729	96.7 (0.6)	99.5 (0.6)	.734	.474
Mexican American	4,085	97.2 (0.4)	98.6 (0.3)	1,676	98.2 (0.7)	99.3 (0.7)	.201	.347
Other	570	90.0 (0.7)	90.5 (0.7)	1,418	91.8 (0.5)	92.5 (0.6)	.050	.034
Education								
< High school	5,470	91.9 (0.5)	95.1 (0.4)	2,464	94.0 (0.6)	97.1 (0.4)	.007	.001
High school graduate or equivalent	4,533	93.8 (0.4)	96.7 (0.3)	2,145	94.4 (0.5)	97.3 (0.4)	.404	.243
> High school	4,271	96.6 (0.5)	98.7 (0.4)	4,406	96.6 (0.3)	98.9 (0.4)	.993	.825
Smoking status								
Current	3,988	89.1 (0.4)	94.7 (0.4)	2,118	90.1 (0.6)	96.6 (0.5)	.192	.002
Former	3,403	95.7 (0.5)	98.7 (0.4)	2,086	95.5 (0.5)	98.3 (0.5)	.792	.569
Never	6,968	97.2 (0.4)	97.7 (0.4)	4,816	97.7 (0.3)	98.7 (0.3)	.338	.048

Data are presented as mean (SE). See Table 1 legend for expansion of abbreviations.

[a] *P* value for test of difference in means between the two time periods.

[b] Unweighted sample size. Sample sizes for education and smoking status add to less than 14,360 due to missing data for these variables.

Table 5

Age-Adjusted and Age-Specific Prevalence of Classes of Obstructive Impairment Based on Spirometry Among US Adults Aged 20 to 79 Years, by Selected Characteristics and NHANES Survey

	NHANES III (1988-1994)							NHANES 2007-2010								
		Impairment							Impairment							
				Obstructive							Obstructive					
Characteristics	No.[a]	None	Restrictive	Mild	Moderate	Severe	Any	No.[a]	None	Restrictive	Mild	Moderate	Severe	Any	*P* Value[b]	*P* Value[c]
Total	14,360	77.8 (0.6)	7.6 (0.4)	7.3 (0.3)	5.7 (0.3)	1.5 (0.2)	14.6 (0.5)	9,024	79.9 (0.6)	6.5 (0.5)	7.5 (0.4)	5.4 (0.3)	0.7 (0.1)	13.5 (0.6)	< .001	.178
Men	6,729	75.4 (0.9)	6.5 (0.6)	9.8 (0.5)	6.6 (0.5)	1.7 (0.2)	18.1 (0.8)	4,487	76.2 (0.9)	6.9 (0.6)	10.1 (0.5)	6.1 (0.5)	0.7 (0.2)	16.8 (0.8)	.006	.262
Women	7,631	79.9 (0.6)	8.5 (0.6)	5.1 (0.3)	5.0 (0.3)	1.4 (0.2)	11.5 (0.6)	4,537	83.5 (0.6)	6.1 (0.5)	5.0 (0.5)	4.7 (0.5)	0.7 (0.1)	10.4 (0.7)	< .001	.199
Age																
20-39 y	6,524	90.5 (0.6)	5.0 (0.6)	2.7 (0.4)	1.6 (0.3)	*d*	4.5 (0.4)	3,318	91.2 (0.8)	4.0 (0.5)	2.9 (0.4)	1.8 (0.3)	*d*	4.7 (0.6)	*d*	.721
40-59 y	4,184	76.7 (0.9)	8.2 (0.6)	7.4 (0.5)	6.2 (0.6)	1.5 (0.2)	15.1 (0.8)	3,229	77.8 (1.1)	7.1 (0.7)	8.4 (0.9)	5.9 (0.6)	*d*	15.0 (1.2)	*d*	.954
60-79 y	3,652	52.7 (1.3)	12.0 (0.8)	17.2 (0.9)	13.6 (0.8)	4.5 (0.6)	35.3 (1.4)	2,477	59.9 (1.5)	10.6 (0.9)	15.5 (1.0)	11.8 (1.0)	2.2 (0.5)	29.4 (1.3)	.004	.002
Race or ethnicity																
White	5,539	78.1 (0.6)	6.5 (0.5)	7.9 (0.4)	5.9 (0.3)	1.6 (0.2)	15.4 (0.6)	4,201	79.5 (0.7)	5.2 (0.5)	8.7 (0.4)	5.9 (0.4)	0.7 (0.1)	15.3 (0.6)	< .001	.865
Black	4,166	78.9 (0.8)	9.5 (0.6)	5.3 (0.5)	5.4 (0.5)	0.9 (0.2)	11.6 (0.7)	1,729	82.0 (0.8)	7.3 (0.7)	5.5 (0.5)	4.2 (0.5)	1.0 (0.3)	10.7 (0.8)	.081	.403
Mexican American	4,085	84.6 (0.9)	6.7 (0.4)	4.7 (0.4)	3.3 (0.4)	0.7 (0.1)	8.7 (0.6)	1,676	87.5 (0.8)	6.2 (0.6)	4.0 (0.5)	2.1 (0.4)	*d*	6.3 (0.5)	*d*	.002
Other	570	70.3 (2.3)	17.7 (2.3)	4.5 (1.3)	5.7 (1.2)	*d*	12.0 (1.6)	1,418	75.1 (1.7)	15.2 (1.5)	4.1 (0.9)	4.8 (0.9)	*d*	9.7 (1.2)	*d*	.264
Education																
< High school	5,470	72.7 (1.2)	11.0 (0.7)	5.9 (0.6)	8.2 (0.7)	2.1 (0.4)	16.2 (1.0)	2,464	77.5 (1.0)	8.2 (0.9)	6.5 (0.7)	6.6 (0.7)	1.3 (0.3)	14.3 (1.2)	.011	.213
High school graduate or equivalent	4,533	77.1 (0.7)	7.9 (0.7)	7.2 (0.6)	6.3 (0.4)	1.4 (0.3)	15.0 (0.8)	2,145	77.5 (1.7)	6.8 (0.9)	8.2 (0.9)	6.5 (0.6)	1.0 (0.2)	15.7 (1.2)	.372	.595
> High school	4,271	81.2 (0.7)	5.3 (0.5)	8.3 (0.6)	4.1 (0.4)	1.2 (0.2)	13.5 (0.8)	4,406	81.8 (0.7)	5.8 (0.6)	7.5 (0.5)	4.5 (0.3)	0.4 (0.1)	12.4 (0.6)	.014	.279
Smoking status																
Current	3,988	67.7 (0.9)	8.3 (0.7)	9.4 (0.8)	10.8 (0.7)	3.8 (0.4)	24.0 (0.9)	2,118	66.4 (1.3)	7.2 (0.8)	11.3 (0.9)	13.0 (0.8)	2.1 (0.4)	26.4 (1.0)	.008	.086
Former	3,403	78.4 (1.2)	6.0 (0.7)	8.9 (0.7)	5.5 (0.5)	1.2 (0.2)	15.6 (1.0)	2,086	78.8 (1.3)	6.1 (0.7)	8.8 (0.7)	5.7 (0.6)	0.7 (0.2)	15.2 (1.0)	.415	.735
Never	6,968	83.5 (0.9)	8.2 (0.7)	4.8 (0.4)	2.9 (0.3)	0.6 (0.1)	8.2 (0.6)	4,816	85.4 (0.6)	6.5 (0.5)	5.2 (0.4)	2.5 (0.3)	*d*	8.0 (0.6)	*d*	.799

Data are presented as percent (SE). See Table 1 legend for expansion of abbreviations.

[a]Unweighted sample size. Sample sizes for education and smoking status add to less than 14,360 due to missing data for these variables.

[b] *P* values for comparisons of the distribution of categories of lung function status for the two time periods.

[c] *P* values for comparisons of the prevalence of any obstructive impairment for the two time periods.

[d] Estimate does not meet the standard of statistical reliability and precision (relative SE ≥ 30%).

Table 6

Age-Specific and Age-Adjusted Prevalence of Airway Obstruction Based on Spirometry Among US Adults Aged 20 to 79 Years

Characteristics	NHANES III (1988-1994)		NHANES 2007-2008		*P* Value
	No.	< FEV_1/FVC LLN Predicted, % (SE)	No.	< FEV_1/FVC LLN Predicted, % (SE)	
Total	14,360	13.3 (0.6)	9,024	12.5 (0.5)	.303
Men	6,729	14.6 (0.7)	4,487	13.7 (0.9)	.460
Women	7,631	12.3 (0.7)	4,537	11.4 (0.7)	.335
Age					
20-39 y	6,524	8.9 (0.6)	3,318	10.1 (0.8)	.209
40-59 y	4,184	14.2 (0.9)	3,229	13.5 (1.1)	.625
60-79 y	3,652	21.0 (1.1)	2,477	15.6 (0.8)	< .001
Race or ethnicity					
White	5,539	14.0 (0.7)	4,201	13.8 (0.6)	.797
Black	4,166	11.9 (0.7)	1,729	11.9 (0.9)	.992
Mexican American	4,085	10.4 (0.6)	1,676	8.3 (0.6)	.015
Other	570	9.4 (2.0)	1,418	8.1 (1.2)	.589
Education					
< High school	5,470	16.2 (1.2)	2,464	14.4 (1.0)	.268
High school graduate or equivalent	4,533	13.3 (0.7)	2,145	15.0 (1.2)	.226
>High school	4,271	11.7 (0.8)	4,406	11.0 (0.6)	.463
Smoking status					
Current	3,988	23.0 (0.9)	2,118	25.6 (1.0)	.051
Former	3,403	13.0 (0.9)	2,086	12.1 (1.1)	.537
Never	6,968	7.6 (0.6)	4,816	7.9 (0.6)	.769

LLN = lower limit of normal. See Table 1 legend for expansion of other abbreviations.

Table 7

Adjusted Prevalence Ratios for the Association of Selected Characteristics With Any Obstructive Impairment and Severe Obstructive Impairment Among Adults Aged 20 to 79 Years, NHANES

	Original Analysis (n = 23,285)		Sensitivity Analysis 1 [a] (n = 23,392)		Sensitivity Analysis 2 [b] (n = 23,379)	
Characteristics	**Any Obstructive Impairment**	**Severe Obstructive Impairment**	**Any Obstructive Impairment**	**Severe Obstructive Impairment**	**Any Obstructive Impairment**	**Severe Obstructive Impairment**
No. with obstructive impairment	3,204	279	3,311	386	3,298	373
Age (per year)	1.05 (1.05-1.05)	1.08 (1.07-1.09)	1.05 (1.05-1.05)	1.08 (1.07-1.09)	1.05 (1.05-1.05)	1.08 (1.07-1.08)
Sex						
Male	1.43 (1.31-1.57)	0.93 (0.66-1.30)	1.42 (1.29-1.55)	0.94 (0.72-1.22)	1.41 (1.29-1.54)	0.89 (0.69-1.14)
Female	1.00	1.00	1.00	1.00	1.00	1.00
Race or ethnicity						
White	1.00	1.00	1.00	1.00	1.00	1.00
Black	0.70 (0.63-0.79)	0.77 (0.50-1.18)	0.73 (0.66-0.82)	1.13 (0.82-1.56)	0.72 (0.64-0.81)	0.96 (0.71-1.30)
Mexican American	0.46 (0.39-0.53)	0.41 (0.23-0.73)	0.46 (0.40-0.53)	0.43 (0.26-0.70)	0.46 (0.40-0.54)	0.44 (0.27-0.71)
Other	0.77 (0.63-0.93)	1.27 (0.69-2.34)	0.78 (0.65-0.95)	1.43 (0.90-2.26)	0.78 (0.65-0.94)	1.36 (0.84-2.21)
Education						
< High school	1.00	1.00	1.00	1.00	1.00	1.00
High school graduate or equivalent	1.02 (0.92-1.14)	0.79 (0.54-1.15)	1.01 (0.91-1.13)	0.79 (0.58-1.09)	1.01 (0.91-1.12)	0.74 (0.54-1.02)
> High school	0.96 (0.86-1.07)	0.61 (0.40-0.93)	0.95 (0.85-1.06)	0.61 (0.44-0.85)	0.94 (0.84-1.05)	0.52 (0.36-0.74)
Smoking status						
Current	2.93 (2.60-3.31)	6.70 (4.02-11.15)	2.92 (2.59-3.29)	5.78 (3.80-8.78)	2.97 (2.63-3.35)	7.52 (4.80-11.78)
Former	1.66 (1.47-1.88)	2.26 (1.40-3.63)	1.67 (1.48-1.89)	2.38 (1.61-3.53)	1.69 (1.50-1.91)	2.98 (1.99-4.47)
Never	1.00	1.00	1.00	1.00	1.00	1.00
NHANES						
1988-1994	1.00	1.00	1.00	1.00	1.00	1.00
2007-2010	1.06 (0.96-1.16)	0.61 (0.42-0.88)	1.09 (0.99-1.20)	1.14 (0.87-1.50)	1.09 (0.99-1.20)	1.12 (0.84-1.50)

Data are presented as prevalence ratio (95% CI) unless indicate otherwise. Each prevalence ratio is adjusted for other variables in table. See Table 1 legend for expansion of abbreviations.

[a] Sensitivity analysis 1: participants who reported using oxygen were considered to have a severe obstructive impairment.

[b] Sensitivity analysis 2: participants who reported using oxygen and reported having COPD, as well as those who reported having a problem taking a deep breath and reported having COPD, were considered to have a severe obstructive impairment.